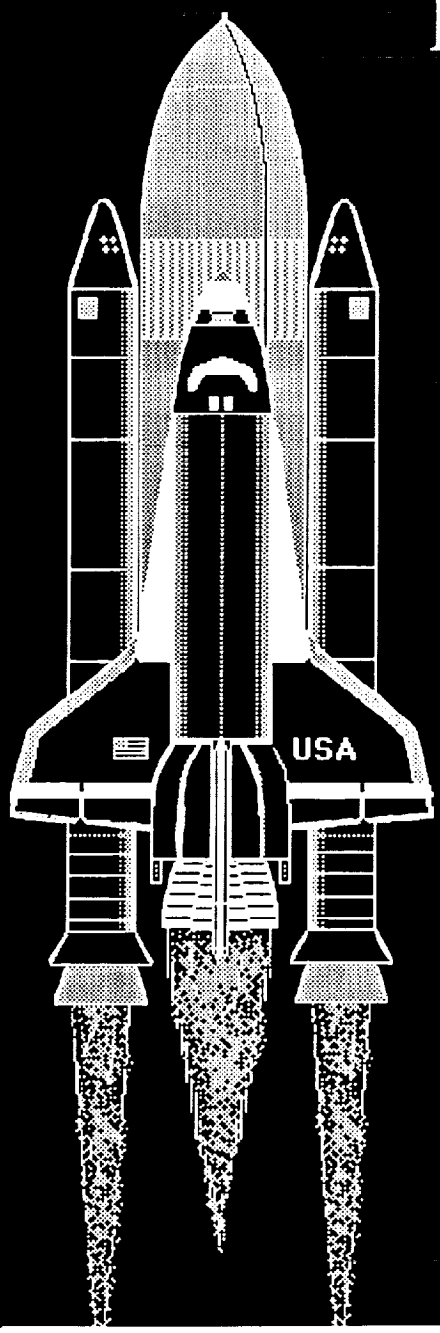
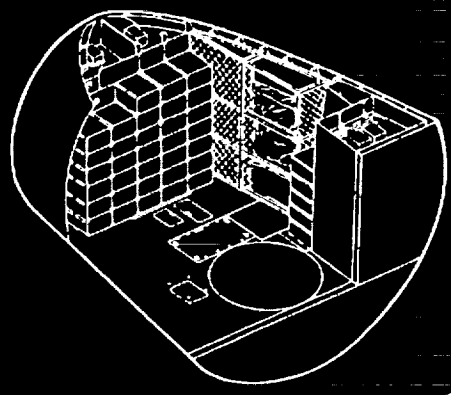
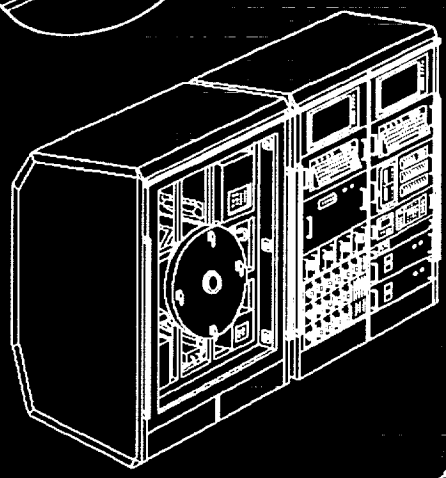
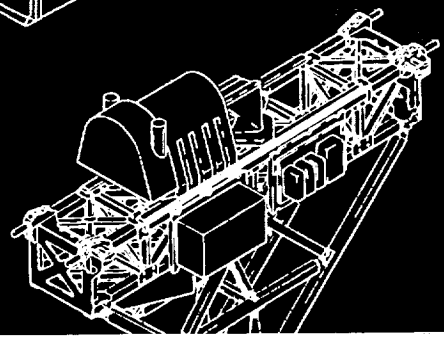
Office of Space Science and Applications
Microgravity Science and Applications Division

Microgravity Program Strategic Plan 1991









NASA
National Aeronautics and Space Administration

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MISSION STATEMENT

As part of its mandate to guide the United States' civil space program, the National Aeronautics and Space Administration (NASA) is committed to preserving U.S. preeminence in critical aspects of space science, applications, and technology. NASA's goals include obtaining scientific, technological, and economic benefits through space-related activities, encouraging U.S. private sector investment in space, and improving the quality of life on Earth.

The NASA Office of Space Science and Applications (OSSA) is responsible for planning and executing the basic and applied research activity associated with these goals. The *Microgravity Science and Applications Division* (MSAD) is responsible to OSSA for administering NASA's microgravity science program. The *Office of Commercial Programs* (OCP) is responsible for facilitating the commercial use of space and its associated applied research through its Commercial Development Division.

Both organizations must work closely with one another to insure a comprehensive NASA-wide *Microgravity Program*. The program's mission is to use the unique characteristics of the space environment, primarily the near-absence of the affects of gravity, to expand man's knowledge of physics, chemistry, biotechnology, and materials and fluid sciences, to understand the role of gravity in materials processing. And, where possible, it seeks to demonstrate the feasibility of using the space environment to obtain data or improved materials that may have high technological or commercial utility.

INTRODUCTION

The all-encompassing objective of the NASA Microgravity Program is the use of space as a laboratory to conduct research and development. The on-orbit microgravity environment, with its substantially reduced buoyancy forces, hydrostatic pressures, and sedimentation, enable us to conduct scientific investigations not possible on Earth. This environment allows processes to be isolated and controlled—and measurements to be made—with an accuracy that cannot be obtained in the terrestrial environment. Many of these processes also play dominant roles in diverse Earth-based technologies as well as technologies that support NASA's overall goals for future extraterrestrial exploration. The low gravity environment therefore demands investigation both for scientific and technological reasons.

The Microgravity Science and Applications Division has defined three major science categories in order to develop a program structure. The areas of research and development to be conducted in space encompass:

1) Fundamental science, including the study of the behavior of fluids, transport phenomena, condensed matter physics, and combustion science;

2) Materials science, including electronic and photonic materials, metals and alloys, and glasses and ceramics;

3) Biotechnology, focusing on macromolecular crystal growth as well as cell and molecular science.

Experiments in these areas typically seek to provide observations of complex phenomena and measurements of physical attributes with a precision that is enhanced by the microgravity environment. These results are used to challenge and validate contemporary scientific theories.

Applied microgravity research, conducted by NASA with its academic and industrial partners, could provide fundamental insights that lead to a better understanding of Earth-based industrial processes and/or the space-based production of new materials with unique properties. Driven by industrial or commercial objectives, this kind of research could lead toward the practical exploitation of such knowledge. Pioneering scientific efforts such as these will stimulate exciting developments in technology and space commercialization that will contribute to the economic growth of the United States in the 21st Century.

The successful exploitation and development of the near-Earth space environment, as well as the exploration and utilization of extraterrestrial bodies, requires a vision of the future with well-defined goals — using a good mix of launch vehicles and research platforms like the National Space Transportation System (Space Shuttle) expendable launch vehicles, free flyers, and space station facilities. In turn, these goals should be consistent with national interests and well conceived, strategic development and operational plans.

Strategic Plan for the Microgravity Program

This document is NASA's agency-wide strategic plan for the Microgravity Program. It addresses research, applications and commercialization for the 1990's. The plan presents our:

- **VISION OF THE FUTURE** — Sets the stage for—and states our beliefs in—the future role of microgravity research;
- **MICROGRAVITY PROGRAM GOALS** — Delineates our purpose and program goals,
- **APPROACH** — Defines the methodologies by which NASA's Microgravity Program is executed;
- **PRESENT STATUS** — Outlines the factors that are shaping the program today;
- **DECISION RULES AND PRIORITIES** — Defines the basic structure for decision making in the Microgravity Program;
- **IMPLEMENTATION STRATEGIES** — Describes in more detail our near term objectives.

L. A. Fisk
Associate Administrator for
Space Science and Applications;

J.T. Rose
Assistant Administrator for
Commercial Programs

VISION OF THE FUTURE

The use of space as a laboratory for conducting experimental, applied, and commercial research in the microgravity environment will continue to increase in the coming decades. An expanded and strengthened infrastructure for microgravity research will exist in which a broad community of researchers will participate. New areas of microgravity research will emerge. Improved ground and space-based facilities will be in place. Orbiting platforms and free flyers will be used for research requiring a long duration, high quality microgravity environment with minimal human intervention. The United States will continue its preeminence in space research and applications through shuttle flights and the operation of a space station in low-Earth orbit. Indeed, a permanently manned orbiting facility will afford the United States and its international partners significant benefits.

Program ground-based and space-borne research will:

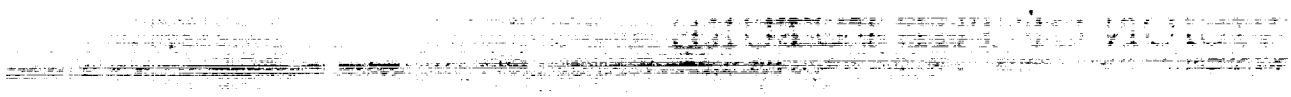
1) Contribute substantially to the knowledge and understanding of fundamental science;

2) Build foundations for new techniques in Earth-based materials processing through advances in materials science;

3) Enhance our quest to understand the growth, structure and regulatory processes of biological molecules, cells and tissues.

The knowledge we have gained about gravity dependent processes will also be applied to Earth-based and space-based industrial processes. It will become the basis for new industrial markets and growth as well as improved products, and it will be utilized by space system planners and designers as they formulate new mission scenarios.

The ***Microgravity Strategic Plan*** for 1991 sets forth a broad, comprehensive program theme. It is reflected in a list of six supporting goals as well as a strategy to attain them, and it will allow NASA to proceed in a cost effective and timely manner.



GOALS OF THE NASA MICROGRAVITY PROGRAM

The following theme and goals for the NASA Microgravity Program reflect a merging of visions of the future and considerations of the current status of the program with space science, applications and commercialization objectives. The Program's thematic purpose is to:

Develop a comprehensive research program in fundamental sciences, materials science, and biotechnology for the purpose of attaining a structured understanding of gravity-dependent physical phenomena and those physical phenomena made obscure by the affects of gravity.

THE MICROGRAVITY PROGRAM THEME REFLECTS THE FOLLOWING GOALS

Goal 1 — Define and conduct a broadly-based Microgravity Science and Applications Research Program in the physical, chemical and biological sciences.

Goal 2 — Enable the Microgravity Research Program by supporting or fostering the development of suitable flight instrumentation.

Goal 3 — Foster the growth of an interdisciplinary research community, united by shared goals and resources, to conduct basic research in the space environment.

Goal 4 — Promote United States industrial involvement and investment in the application of space research for the development of new, commercially viable products, services, and markets resulting from research in the space environment.

Goal 5 — Utilize future space station capabilities together with other carriers, such as free-flying platforms and extended-duration orbiters, to provide the optimum experiment/carrier combination for maximizing science return.

Goal 6 — Provide for international cooperation and coordination in conducting space-related basic and applied research, while maintaining the Unites States' competitive commerical position.

MICROGRAVITY PROGRAM APPROACH

The *Microgravity Science and Applications Division* (MSAD) conducts a program of basic research on the ground and in space for NASA's Office of Space Science and Applications (OSSA). Its purpose is to expand man's knowledge of chemistry, physics, combustion, and materials and fluid sciences. In addition, the Division pursues applied research in materials science and biotechnology to enable technological advances in these critical areas. NASA-funded investigations are conducted by university, industry and government researchers using both ground-based facilities and aerospace flight instruments.

The Division uses an evolutionary approach to conduct space research of the highest quality. The process starts with new ideas proposed by individuals or teams of investigators. These proposals are then peer reviewed. If accepted, they are approved for ground-based or flight development, depending on the maturity of the concept. New ideas undergo ground-based definition to afford an opportunity for progress in supporting theory and the collection of experimental data, and to develop sharply focused flight objectives.

Some hypotheses may be refined or confirmed and their associated flight objectives validated using ground-based, reduced-gravity facilities. In these facilities, reduced-gravity test environments of varying durations—up to 5 seconds in drop towers and drop tubes, 30 seconds in aircraft, and 15 minutes in suborbital rockets—are available. To support these investigations (as well as those requiring longer periods of reduced gravity) in the most cost effective manner, the flight program uses a broad base of hardware and carrier resources.

The Division cooperates with our international partners by establishing, through NASA's Office of External Relations, international working groups with one or more nations or agencies, and/or through bilateral agreements with other individual governments. Typically, NASA provides access to space while our foreign partners provide the flight hardware, and the science investigations are then shared by the involved countries. Also, United States-led investigations may have foreign co-investigators. In this manner the program attempts to share and maximize the science return while minimizing the total experiment cost.

The Division recently established a formal cooperative program through which opportunities for U.S. investigators to propose the use of foreign hardware will be offered. International cooperative efforts to develop the next generation of experiment hardware also are

underway. Experience gained through hardware development in one country can be shared and used to effect future hardware development in another. Every effort is made to maintain an open exchange while protecting individual rights to designs, data and technologies.

The Division works with and receives guidance from several advisory groups. For example, program content is reviewed periodically by the *Microgravity Science and Applications Subcommittee*, and the *Space Station Science and Applications Advisory Subcommittee* continues to review the program with regard to space station utilization. Both are subcommittees of the *Space Science and Applications Advisory Committee* that reviews the activities of the Office of Space Science and Applications and, in turn, forms a portion of the NASA Advisory Council. The *Committee on Microgravity Research* (under the Space Studies Board of the National Research Council) reviews the Microgravity Program as well as programs of other agencies, industry, and academia to assure a complementary overall program that meets national needs.

Science Discipline Working Groups also have been established for the major areas of the program, reporting through the discipline program scientists. They are responsible for maintaining an overview of the efforts in the discipline areas, identifying the programs' strengths and weaknesses as well as the most promising areas for investigation and the most advantageous approaches for experimentation.

An advanced technology development effort is conducted by the Division to cultivate advanced measurement techniques and experimental methodologies that are necessary to support future science investigations. As future technology needs are identified, the Division works with other NASA offices to create and execute the most cost effective method of meeting the needs. These efforts may take the form of actual development of new technologies or of customizing existing technologies in order to best meet the needs of future microgravity investigations.

The *Office of Commercial Programs* (OCP) sponsors focused industrial research and program initiatives that encourage the participation of United States industry in commercial space endeavors. OCP-sponsored *Centers for the Commercial Development of Space* represent the mechanism through which universities and non-profit institutes—with committed industry partnerships—participate in an industry-driven, commercial microgravity research program. NASA provides seed money to develop research centers at universities and non-profit organizations that are also supported by industry contributions.

The OCP-sponsored *Centers for the Commercial Development of Space* form partnerships with various industries that share a common interest in—and commitment to—focused and/or applied space research. The amount of commercial commitment and actual contribution represents a major consideration in implementing such activities. There are presently five such centers committed to commercial microgravity research in materials processing. These centers provide an excellent mechanism for combining academic and industrial research to ensure that experiments have commercial objectives.

In addition to flying an experiment on a Space Shuttle mission through a commercial development center, industry can also propose payloads directly through a *Joint Endeavor Agreement* (JEA), a *Space System Development Agreement* (SSDA), or a *Launch Services Agreement* (LSA). Each type of agreement enables industry to fly payloads in space at different phases in the product cycle. Using the method discussed in the first two paragraphs of this section, scientific investigations proposed by industrial researchers may also compete for funding from the Microgravity Science and Applications Division. Furthermore, commercially developed hardware and systems can be utilized to achieve the Division's experiment objectives.

The OCP's principal role in the commercial development of space is to promote the involvement and investment of U.S. private industry in the commercial development of space. This role includes providing flight opportunities that address industry-driven technology requirements. Industry requires a vigorous, high quality research program in which frequent flight opportunities, prompt review procedures, and rapid reporting of results provide the data needed to understand physical phenomena from which commercial ventures can confidently emerge. A large measure of NASA's success in developing the space frontier will be the degree to which industry, universities and other government agencies participate and/or invest in space research, development and commercialization efforts.

CURRENT STATUS

Microgravity Science and Applications Division

The *Microgravity Science and Applications Program* is now entering a phase of highly active flight experiment activity. Two more protein crystal growth experiments and the first microgravity combustion experiment flew in 1990, and all were highly successful. The coming year will witness the launch of the first of the International Microgravity Laboratory (IML) series of flights. It will carry multiple flight experiment payloads built by investigators from both the United States and its international partners. Division experiments will also fly on several other shuttle missions in 1991. Additional near-term opportunities for Division payloads are the United States Microgravity Laboratory (USML) and the United States Microgravity Payload (USMP) series of flights, both scheduled to begin in 1992.

The Division's mission planning schedule is shown Figure1. It identifies the major microgravity missions and the hardware to be flown on them. The figure provides a clear picture of when each of the missions is to take place. For example, the Fluid Experiment System will fly on IML-1 in 1991; Protein Crystal Growth will fly on IML-1 in 1991 and on three additional middeck flights. The planning schedule also reveals how the Division continues to participate with our foreign and commercial partners by using and sharing hardware, and by sponsoring investigations associated with foreign hardware that will fly on specified USML, IML and USMP missions.

The Cooperative Program that is reflected in the mission planning schedule was recently established to provide additional opportunities for U.S. investigators to propose use of foreign hardware. It is planned that this program will sponsor two middeck flights per year in 93, 94 and 95. Additional opportunities using various European carriers are also being examined. The Division is also sponsoring an investigation on the commercially developed *Crystals by Vapor Transport Experiment* payload. The mission planning schedule shown in Figure1 is consistent with the February, 1991, mixed-fleet manifest. This schedule and the overall Division flight program will continue to evolve as programmatic decisions are made.

As a further adjunct to the flight program, a new initiative is under consideration to support a number of significant fundamental science experiments that are now ready to proceed into flight development. Numerous peer reviews have determined that the scientific merit of the experiments warrant flight opportunities. However, these flight

experiments generally lie outside the current and planned microgravity flight hardware capabilities. The Division is now exploring options for the use of suborbital rockets and free-flyers for experiments that do not require the longer shuttle flights and/or manned interactions.

In the latter part of the 1990's, Space Station *Freedom* could be ready to provide additional capabilities to conduct microgravity research, particularly with respect to greater experiment duration and flexibility. Several multiuser microgravity facilities are now being defined for potential use on the space station, and hardware requirements necessary to support the facilities are being identified in order to influence space station design. Precursor payloads flown on shuttle missions will provide experience with operations and the development of instrumentation and subsystems for use in the space station facilities. Additional emphasis will be placed on development of telescience and automation in order to effectively use the space station and free-flyer platforms.

In a further attempt to maximize the early use of the space station, a study is also under way to examine the feasibility of using appropriate hardware on the space station that was originally built for Spacelab. This study will define the scientific plausibility of performing experiments on the space station with the proposed hardware, as well as cost and schedule performance for any modifications required. In support of the overall flight program, the Division has recently undertaken a study of its own hardware development to examine how flight hardware cost estimates were generated and what influenced cost growth as the projects progressed. The results of this study will supply the needed insight to allow the appropriate measures to be taken such that future hardware development cost growth can be minimized.

The ground-based program continues to perform its essential, historical functions of providing theoretical and experimental efforts to support and thoroughly understand the results of current flight experiments, and to nurture ideas and efforts that may later form the basis of flight experiments. The additional resources necessary to maintain the level of experimental effort needed to produce the high quality flight experiments of the future is the subject of an augmentation proposed for the early 1990's. In addition, a NASA Research Announcement (NRA) was issued to solicit ground-based and flight combustion experiments during 1990. As a result of that solicitation, approximately 65 proposals were received. Of these, 6 were funded for flight experimentation and 12 for ground-based experimentation. An NRA for Containerless Processing was released late in 1990; that proposal evaluation process also has been completed, and funding decisions are currently being defined.

Figure 1. Microgravity Science and Applications Division Mission Planning Schedule

Flight Experiment	CY91	CY92	CY93	CY94	CY95	CY96	CY97	CY98	CY99	CY00
Fluid Experiment System	IML-1						USML-3			
Vapor Crystal Growth System	IML-1						USML-3			
Protein Crystal Growth	MD(3)/ IML-1	USML-1 SL-J								
Space Acceleration Measurement System	MD/IML-1 SLS-1	MD(1)/SL-J USML-1 USMP-1	MD(2) USMP-2	IML-2 USMP-3 MD(2)	MD(2) USMP-4 USML-2	MD(2) USMP-5	USML-3 MD(2)	MD(2)	MD(2)	MD(2)
Solid Surface Combustion Experiment	MD(2)/SLS-1	USML-1/MD(2)	MD				USML-3			
Gallium Arsenide Experiment	SLS-1	GAS								
Cryostat (F)	IML-1									
Critical Point Facility (F)	IML-1			IML-2						
Drop Physics Module		USML-1			USML-2		USML-3			
Crystal Growth Furnace		USML-1			USML-2		USML-3			
Surface Tension Driven Convection Experiment		USML-1					USML-3			
Glovebox		USML-1			USML-2		USML-3			
Lambda Point Experiment		USMP-1				USMP-5				
Pool Boiling Experiment		GAS	GAS	GAS						
MEPHISTO (F)		USMP-1	USMP-2	USMP-3	USMP-4	USMP-5				
Crystals by Vapor Transport Experiment (U)		MD								
Advanced Protein Crystal Growth			MD(4)	MD(4)	USML-2/MD(3)	MD(4)	MD(4)/USML-3	MD(4)	MD(2)	MD(4)
Adv Automated Directional Solidification Furnace			USMP-2	USMP-3	USMP-4	USMP-5				
Critical Fluid Light Scattering			USMP-2							
Isothermal Dendrite Growth Experiment			USMP-2		USMP-4	USMP-5				
BIOLABOR (F)			SL-D2							
Cooperative Program			MD(2)	MD(2)	MD(2)					
Advanced Protein Crystal Facility (F)				IML-2						
TEMPUS (F)				IML-2						
Bubble Drop and Partical Unit (F)				IML-2						
Free Float Electrophoresis Unit (F)				IML-2						
RAMSES (F)				IML-2						
Large Isothermal Furnace (F)				IML-2						
Geophysical Fluids Flow Cell					USML-2					
Advanced Combustion Middeck Modules						MD	MD	MD	MD	MD
Advanced Fluids Middeck Modules							MD	MD	MD	MD
Advanced Combustion Spacelab Module							USML-3			
Programmable Multi-Zone Furnace							MD	MD(2)	MD	MD(2)
Critical Fluid Viscosity Measurement Experiment						USMP-5				
Advanced Protein Crystal Growth Facility								SSF →	→	→
Fluid Physics & Dynamics & Combustion Facility							SSF →		→	→
Space Station Furnace Facility								SSF →	→	→
Modular Containerless Processing Facility									SSF →	→
Fundamental Science Facility									SSF →	→
Small & Rapid Response Payloads									SSF →	→

NOTES:
- IML 1 - 5: International Microgravity Laboratory Mission 1 through 5
- USML 1 - 5: United States Microgravity Laboratory Mission 1 through 5
- USMP 1 - 5: United States Microgravity Payload Mission 1 through 5
- SLS-1: Spacelab Life Sciences Mission 1
- SSF: Space Station Freedom
- SLJ: Japanese Spacelab
- SL-D2: German Spacelab
- GAS: Getaway Special
- (F): Indicates foreign hardware on which MSAD investigators are flying
- (U): Indicates U.S. non-MSAD hardware on which MSAD investigators are flying
- MD: Middeck (numbers in parentheses after MD indicate number of MD flights per year)

Mission planning schedule will evolve as programmatic decisions are made [based on the February 1991 Mixed Fleet Baseline Manifest]

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The Division is developing plans for the release of additional Announcements of Opportunity (AO) and NRA's that will be used to sustain the effort to conduct high quality scientific investigations. Upon acceptance for the ground-based program, a Principal Investigator (PI) can pursue a three-year project that is reviewed annually. In the flight program, an investigator is funded for definition or flight development, depending on the experiment's initial level of maturity. The transition from experiment definition to flight development is accomplished via a structured review process that examines the scientific and technical progress of the investigation.

The President's speech of July 20, 1989, highlighted a new program, now called the *Space Exploration Initiative* (SEI). It called for a permanently manned lunar base and a Mars outpost for research and resource development. More recently, the *Advisory Committee on the Future of the U.S. Space Program* stated that it shared the President's view that the "long term magnet for the manned space program is the planet Mars." The committee challenged NASA and the country to adopt a comprehensive goal and program of exploration entitled "Mission from Planet Earth," which calls for unmanned and manned exploration of the solar system. It includes a lunar base and the manned exploration of Mars. The microgravity program is in a position to support these efforts by developing a thorough understanding of those physical phenomena affected by gravity. That understanding will strengthen the scientific foundation needed for those technologies required for safe and efficient operations in interplanetary travel and extraterrestrial environments.

Office of Commercial Programs

Approximately 61 technology activities have been identified by the Office of Commercial Programs, and these activities will be conducted as elements of more than 300 experiments to be flown by the end of the decade. Many of OCP's flight requirements will be accommodated on shuttle orbiters, which afford the use of the commercial middeck augmentation module, but other key activities will be accomplished via expendable launch vehicle services acquired through the *COMmercial Experiment Transporter* (COMET) program. In both cases, commercial infrastructure is being fostered and used to directly or indirectly support Commercial Development of Space program objectives. In addition, the significance of space station facilities is incorporated into the OCP strategic plan.

While the objectives and optimum approaches of the Microgravity Science and Applications Division and the Commercial Development of Space program are different, some of the existing projects involve

cooperation on the basis of principals or the shared use of hardware. In particular, further opportunities to share hardware capabilities are expected to materialize — to the benefit of both programs. The Commercial Development of Space program also makes use of many NASA ground-based facilities and microgravity aircraft to optimize program development. The fundamental needs of industrial research identified in this way are being shared with NASA's Microgravity Science and Applications Division.

In general, a vigorous and promising commercial development program is taking shape. It already reflects major commitments by more than 235 businesses representing at least seven industrial technical disciplines. More than 40 flight activities were attempted during the period from late 1988 through 1990, and more than 60 additional activities are planned for 1991 and 1992. Together, these activities will thoroughly explore the potential for the commercial development of space.

DECISION RULES & PRIORITIES

The use of space as a laboratory for conducting research and development is an endeavor of considerable magnitude and responsibility, but one capable of producing an enriched stream of benefits for our educational system as well as many sectors of our economy. The challenge facing the NASA Microgravity Program is to make optimal use of this laboratory while conducting research in the most cost-effective manner. Therefore, it is necessary to establish decision rules and priorities for both commercial and research activities in order to guide the process.

Commercial Development Activities

NASA's Commercial Development Division operates within space policy for commercial guidelines approved by the President, as well as in accordance with the body of related policy and legislation established by Congress and the Executive Branch. Some of the salient points related to program formulation and execution are as follows:

1. Foster the identification of commercial development of space activities reflecting valid, industry-driven initiatives with commercial endeavor objectives and needs.

2. Allocate flight opportunities available to the Office of Commercial Programs in a manner that most effectively utilizes such resources to further the overall commercial development of space objectives.

3. Facilitate the development and implementation of commercial development payloads in a manner most appropriately responsive to the overall needs of the commercial development of space endeavors.

4. Identify and justify hardware and space transportation needs to satisfy commercial development of space requirements.

5. As appropriate, seek to enhance the incorporation of principles of commerce and commercial endeavors, utilize commercially available products and services, and avoid activities that preclude or deter the natural development of commercial space sector capabilities.

6. Support planning to most effectively exploit space station capabilities that will further the commercial development of space objectives.

7. Seek means for enhancing interaction and synergism between commercial development activities and the activities of the Microgravity Science and Applications Division, to further the overall objectives of the NASA Microgravity Program to the greatest benefit of the United States.

Microgravity Science and Applications Activities

The Microgravity Science and Applications Division develops its decision rules within the bounds of—and closely attuned to—the Strategic Plan of the Office of Space Science and Applications. The microgravity decision rules and the associated priorities are as follows:

1. *Maintain and complete the ongoing program;*

The completion of the ongoing program within Division budget and flight constraints remains the highest priority. This includes the commitment to the USML, IML, and USMP series of flights; the development of apparatus for secondary payloads; and the ground-based science program.

2. *Identify and nurture emerging experimental concepts and areas of investigation which appear to have high scientific value;*

While the completion of the ongoing program must remain the first priority, the development and maturation of emerging flight experiment concepts and areas for scientific investigations represents the immediate second priority. The purpose of this effort is to maintain a vigorous future program. These activities are focused toward expanding microgravity research in emerging fields of science and addressing critical issues identified in the research program.

3. *Move aggressively, but sensibly, toward the capability for experimentation on space station and other advanced carriers, such as commercially developed U.S. systems or the European man-tended free flyer;*

It is likely that future microgravity experimentation will be performed on advanced carriers and platforms like the space station and free flyers. The Division must therefore move aggressively to take

advantage of the unique capabilities of these future carriers. Advanced technology is being developed to support new and innovative experiments on Space Shuttle orbiters, space station, and other advanced carriers. For example, the Division is defining concepts for facilities to be used on the space station to support multiple experiments through the substitution of different modules. Teleoperation technology is being studied in order to support experiments in the absence of continual manned interaction. Studies of advanced free flyers are being conducted to determine the most appropriate fit between the spacecraft and the microgravity experiment requirements.

4. *Selectively identify new initiatives as required to support the Microgravity Program.*

Several opportunities for further efforts have been identified that would significantly enhance the microgravity program. These efforts are under consideration as future augmentations and new initiatives in consonance with OSSA's strategic planning efforts. These include an augmentation to the ground-based *Microgravity Research and Analysis Program,* a new initiative for the *Microgravity Flight Program* to support *Microgravity Fundamental Science,* and an augmentation to support *Space Station Operations Integration and Training.* Brief summaries of these proposed initiatives and augmentations are included in Appendix A.

IMPLEMENTATION STRATEGIES

The six major Microgravity Program goals restated in this section will be achieved through the flight experiment and ground-based programs via the execution of strategies identified below:

Goal 1 — Define and conduct a broadly-based Microgravity Science and Applications Research Program in the physical, chemical and biological sciences.

- Follow an evolutionary approach to research wherein experiments are first developed on the ground — tested, refined, and carefully selected for shuttle flights; where appropriate, they can then be continued on free flyers or as space station payloads.
- Use a structured review process, including the *Conceptual Design Review* and the *Requirements Definition Review* to maximize the return on in-space research.
- Provide for timely dissemination of post flight science results through the requirement for preliminary and final flight data reports.
- Develop a science database for archival storage of science data.
- Continue to use the Discipline Working Groups to identify program strengths and weaknesses and support development of the microgravity strategic and science plans.
- Continue to use the Microgravity Science and Applications Subcommittee of the Space Science and Applications Advisory Committee for review of program content and direction.
- Continue to use the Space Station Science and Applications Advisory Subcommittee of the Science and Applications Advisory Committee to overview the interaction of the program with the Space Station.
- Continue to use the Committee on Microgravity Research of the Space Studies Board to assure a cohesive policy for use in defining and conducting a national microgravity program.
- Define and propose new initiatives to strengthen appropriate science areas of the flight experiments program.
- Develop and support a Microgravity Science and Applications Division budget inline with OSSA and NASA's goals and objectives.

- Apply the results of the ground based research and flight experiments to the technologies needed to support future NASA missions.

Goal 2 — Enable the Microgravity Research Program by supporting or fostering the development of suitable flight instrumentation.

- Support the delivery of the flight experiment hardware for USML-1, USMP-1, and IML-1 and continue to support the development of flight hardware for the future USML, IML and USMP missions.
- Accommodate emerging high value scientific experiments by identifying flight instrument needs and performing in-house Phase A studies for all promising flight instrument developments.
- Support future hardware development by identification and development of appropriate technologies to enhance measurement accuracies and experiment methodologies.
- Ensure the involvement of the principal investigators in the flight hardware definition and development.
- Support the budget process to provide funds to develop new instrumentation.
- Develop project plans and cost containment and contingency plans including performance, schedule and resource requirements for all new developments.
- Ensure effective integration of the flight hardware through the mission management function.
- Give full consideration to the use of commercially developed hardware to accomplish Microgravity Science and Application Division objectives.
- Enlarge the microgravity measurement analysis effort to characterize the acceleration environment on Spacelab and other spaceflight facilities, and define more precisely the acceptable levels for future experimentation .

Goal 3 — Foster the growth of an interdisciplinary research community, united by shared goals and resources, to conduct basic research in the space environment.

- Support the orderly expansion of the ground-based and flight research efforts via the periodic release of solicitations to obtain high quality research proposals from industry, academia and government.
- Support a vigorous discipline working group infrastructure.
- Continue to support forums and workshops, such as Gordon Research Conferences, American Institute of Aeronautics and Astronautics Aerospace Sciences Meetings, COSPAR Conferences, International Astronautical Federation Conferences, and European Symposia on Material and Fluid Science in Microgravity, which disseminate information to the scientific community-at-large regarding microgravity research.
- Enhance the support of microgravity research in the academic community via development of an undergraduate research program, continued use of graduate student fellowships, and expansion of post-doctoral fellowship awards.
- Pursue involving high school students through an active educational program.
- Encourage government, university, industry cooperation through the Visiting Senior Scientist Program.

Goal 4 — Promote a United States industrial involvement and investment in the application of space research for the development of new, commercially viable products, services, and markets resulting from research in the space environment.

- Continue to support the Centers for the Commercial Development of Space to promote industry/university/NASA research links in order to enhance the U.S. science and technology commercial databases in materials processing and biotechnology.

- Continue to support the Centers for the Commercial Development of Space and their industry partners in the development of technologies, hardware and infrastructure for use in developing and supporting self-sustaining commercial space industries.
- Continue to provide transportation opportunities for commercial flight experiments on Space Shuttle and for Space Station *Freedom*, as well as support for the Centers for Commercial Development of Space in securing flight opportunities on commercially procured sounding rockets and expendable launch vehicles.
- Continue to offer agreements between NASA and private sector entities in order to reduce risks associated with the early stages of commercial space ventures, and to encourage companies to conduct space-related research and development of products and services.
- Continue efforts to lower the barriers to commercial space activities through the promotion of proactive commercial space policies, and through the coordinated efforts of the Commercial Programs Advisory Committee to provide industry-driven advice to the NASA Assistant Administrator for Commercial Programs.
- Maintain coordination with the Technology Utilization Division of the Office of Commercial Programs in order to make use of existing technology transfer methodologies, and to coordinate on the development of new methodologies where appropriate.
- Coordinate the availability and use of both NASA and commercially developed hardware and systems, as appropriate, to further the cost-effective achievement of objectives.

Goal 5 — Utilize future space station capabilities together with other carriers, such as free-flying platforms and extended-duration orbiters, to provide the optimum experiment/carrier combination for maximizing science return.

- Continue to define requirements for facilities and advanced modules which will be designed for use on Space Station *Freedom* or other advanced carriers.
- Conduct Phase A studies on selected space station facilities and advanced experiment modules
- Continue studies to examine the interim use of Spacelab hardware on Space Station *Freedom*.

- Support studies of telerobotic technologies necessary to accomplish experiments in absence of manned presence.
- Evaluate the utility of conducting microgravity experiments as attached payloads to Space Station *Freedom*.
- Continue to review proposed space station designs and recommend changes to enhance the environment for conducting microgravity research.
- Continue to maintain a systems engineering effort to examine subsystem commonality requirements among different experiments and space station facilities to minimize overall experiment module and facility development cost.
- Support the development of integration, operations and training activities associated with space station facilities.
- Facilitate and expand opportunities for the commercial use of Space Station *Freedom* and the provision of space station infrastructure by the private sector.

Goal 6 — Provide for international cooperation and coordination in conducting space-related basic and applied research, while maintaining the United States' competitive commercial position.

- Continue to utilize international interfaces through government agencies and committees for the purpose of identifying and developing areas of mutual interest in basic research.
- Promote participation in the *International Microgravity Laboratory* (IML) and other appropriate missions through solicitations to U.S. and foreign investigators for the use of both foreign and domestic experiments.
- Continue seeking international cooperation for the development and/or use of selected experiments that support and do not compete with U.S. commercial efforts.

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APPENDIX

APPENDIX A

FUTURE INITIATIVES AND AUGMENTATIONS

In order for the Microgravity Science & Applications Division to accomplish its stated goals in the most effective manner, the following new initiatives and augmentations are presently under consideration and are being developed consistent with the OSSA Strategic Plan.

RESEARCH AND ANALYSIS AUGMENTATION
(Proposed Research Base Enhancement)

Historically, the mainstay of the Microgravity Division's program has been the nurturing of high quality, ground-based investigations leading to definition and development of experimentation in the space environment. The principal objective of these ground-based laboratory investigations is to analytically and experimentally advance the state-of-the-art in science and technology disciplines related to NASA's traditional microgravity program, and, where necessary, develop the basis for flight experiments which utilize the space environment to achieve scientific advancements not possible in a 1g environment. Closely coupled with the expansion of the ground-based program is the need for advanced development of measurement, diagnostic, and characterization techniques to facilitate future flight investigations, and for the capability to use suborbital flights to obtain greater experiment time in reduced gravity than that available via ground-based facilities.

The fundamental microgravity research program will be strengthened in several areas:

1. By continuing development of a ground-based research program of sufficient vigor to assure that the widening opportunities for flight experiments in the space station era will be optimally utilized.
2. By enlarging the microgravity measurement analysis efforts to characterize the acceleration environment on Spacelab and other spaceflight facilities, and to define more precisely the acceptable acceleration levels for future experimentation.
3. By enhancing ground-based test facilities.
4. By enhancing the educational opportunities in the college community through undergraduate and post doctoral programs as well as special grant programs to acquaint young investigators with microgravity research.

MICROGRAVITY FUNDAMENTAL SCIENCE FLIGHT INITIATIVE
(Proposed Small Missions Initiative)

A number of fundamental physical and chemical laws can be investigated through access to the low-gravity environment of spaceflight. Investigations in fundamental research using experiment-specific hardware can challenge contemporary theories. Investigators can use Space Shuttle, expendable launch vehicles, sounding rockets, free flyers, Space Station *Freedom*, and possibly commercial platforms as vehicles on which to conduct research of this nature. The scientific merit and desirability of developing specific opportunities in this area are cited by the Space Science Board in *Space Science in the Twenty-First Century: Imperatives for the Decades 1995 to 2015 — Fundamental Physics and Chemistry.*

The purpose of this initiative is to start development of the flight hardware to support these emerging, fundamental science investigations, by:

1. Providing funding to support the Phase A/B studies necessary to adequately identify and scope the resources required to carry out the flight experiment developments;
2. Providing funding necessary for carrier assessment studies in order to match the proposed flight experiment with the most appropriate carrier vehicle;
3. Providing funding necessary to support flight hardware development.

SPACE STATION OPERATIONS INTEGRATION & TRAINING AUGMENTATION
(Proposed Microgravity Flight Program Infrastructure Support)

As planning for Space Station *Freedom* proceeds, the Microgravity Science & Applications Division recognizes the need to prepare for the physical and analytical integration of flight hardware, the operations of that flight hardware, and the training of the investigator teams prior to flight. The purpose of this augmentation is therefore to strengthen the planning to develop an operational philosophy and methodology for—and begin implementing the use of—Space Station *Freedom*, by:

1. Definition and development of the infrastructure required for the analytical and physical integration of the flight hardware;
2. Definition and development of the infrastructure required to support on-orbit experiment operations;
3. Definition and development of the necessary crew training programs;
4. Augmentation of the existing data information management infrastructure.

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* U.S. G.P.O.:1991-282-282-40030